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TRANSMISSION AND ORBITAL CONSTRAINTS IN SPACE-RELATED PROGRAMS:--ETC(U)

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TRANSMISSION AND ORBITAL CONSTRAINTS IN SPACE-RELATED PROGRAMS: BRIEFING SUMMARY

A. L. Hiebert

November 1981

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PREFACE

This briefing summary is an addendum to a Rand Note on "Transmission and Orbital Constraints in Space-Related Programs: Project Description," N-1536-AF, August 1980, prepared for the United States Air Force. Essential components of the project include development of a comprehensive Space Environment Data Base and Analysis Codes and Computer Programs. This capability will provide a resource for evaluating engineering and architectural designs, identifying and analyzing the impact of intentional and unintentional electromagnetic (EM) interference, and predicting probable saturation conditions in spectrum usage of space and earth segments, and satellite/orbital positions. Assessments of ways of accommodating anticipated growth are included in the program.

The briefing was presented at a joint conference on "Space Systems Data Bases and Analysis Capabilities," which was organized to assist Rand and the ECAC in defining the items for inclusion in the data base, its subsequent updating, and evaluating existing and needed analysis programs. Representatives from industry and government agencies were asked to participate. The conference was conducted and hosted by ECAC, on November 17-19, 1981 at Annapolis, MD. ECAC will compile a report on the Proceedings.

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CONTENTS

I. INTRODUCTION

The United States Air Force has a leadership role in the development and operation of space systems for the Department of Defense. Planning for future space-related programs needs to include anticipated growth in number of space systems, including ground networks, large multifunction satellites, increased data-transmission rates, and effects on future requirements for spectrum allocations and orbital positions.

A study project,* sponsored by the Air Force, was initiated to develop a capability for predicting and analyzing the spectrum/orbital geometry requirements of current and projected U.S. and international space-related systems. Essential components of the project include development of a comprehensive space environment data base and computer analysis programs. This capability will provide a resource for evaluating engineering and architectural designs, identifying and analyzing the impact of intentional and unintentional electromagnetic (EM) interference, and predicting probable saturation conditions in spectrum usage and satellite/orbital positions. Assessments of means for accommodating the anticipated growth are also an important part of the study project.

The Directorate of Space Systems and Command, Control, Communications (AF/RDS), Headquarters, United States Air Force is providing support for this project within the Air Force through the

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* A. L. Hiebert and A. F. Brewer, Transmission and Orbital Constraints in Space-Related Programs: Project Description, The Rand Corporation, N-1536-AF, August 1980.

Program Management Directive (PMD) of the Advanced Space Communications Program (PE634431F). AF/RDS is the Office of Primary Responsibility (OPR) for the Rand effort and will assist in requesting the support and participation of other DoD organizations, the FCC, NASA, NTIA, and space-related industries. Rand's work will be coordinated with these agencies. The project will be structured for a continuing analysis program that will comply with technical criteria, rules and regulations, and coordination procedures established by the national and international spectrum management agencies. As projected, the analysis program will be designed to be accessible to the space community as operational capabilities are acquired.

II. PROJECT OBJECTIVES

Projected advances in the use of space by the military and other organizations for communications, navigation, surveillance, and other mission capabilities--coupled with the prospect of substantial increases in launch rates by U.S. military, intelligence, and civil agencies, as well as by international agencies--will add substantially to data link traffic and data-processing requirements in ground-to-satellite, satellite-to-satellite, and satellite-to-ground communications and relay systems. Data transmission requirements could expand by several orders of magnitude as new and larger spacecraft are developed; LANDSAT-D, for example, proposed that resolution be increased from 1.2 acres to 0.2 acre (4850 M^2 to 810 M^2) and that the [illegible]R data rate be increased from 1000 to 1,000,000 bits/sec. Such expansion could severely tax the data-handling capacities of current equipment and affect the frequency spectrum allocations and orbit assignments of satellite systems. Available spectrum, and the useful orbital positions as defined by today's capabilities, may be inadequate. This could negate the operational advantage of the increased sensing capabilities now being sought in spacecraft, and the increased demand in time of crisis could result in disruption of critical data transmission.

The future growth in both commercial and military space systems will be constrained by technical problems associated with the frequency spectrum, orbital congestion, and costs stemming from proliferated terminals. The seriousness of these constraints is shown in an assessment of the useful areas and coverage of the geostationary

circle;* these areas are essentially full at current assignments with communications satellites at C-band and are expected to reach saturation at X and K_u-bands in the future. The military UHF and SHF frequency bands are also almost saturated because large portions of them are shared with terrestrial links.

Future deep-space-based exploration systems may also be characterized by high-data-rate-mission sensors and thus will create additional problems in the use of the frequency spectrum and in data transmission. The high data rates are based on the demand for timely and accurate sensor information covering wide spatial areas and are generated by fast detectors with high sensitivity and resolution. Deep-space exploration sensors are expected to exhibit data rates that will exceed the data transmission capacity of the currently planned communication links and ground-processing equipment.

This briefing outlines the project objectives and tasks required to develop a continuing program for predicting and analyzing the spectrum and orbital requirements of current and future space-related systems, and for predicting potential saturation conditions. p. 5

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* The FCC has acknowledged that additional steps must be taken to meet the continued demand for satellite capacity and to provide for new entry. To address this matter, the FCC has issued a "Notice of Inquiry and Proposed Rulemaking," Docket No. 81-704, November 18, 1981, on the "Licensing of Space Stations in the Domestic Fixed-Satellite Service and Related Revisions of Part 25 of the Rules and Regulations." A reduction in the geostationary orbital space from 4 degrees to 2 degrees between satellites operating in the 4/6 GHz bands, and in spacing from 3 degrees to 2 degrees between satellites operating in the 12/14 GHz bands, is proposed. A 3-dB improvement in earth station antenna sidelobe gain standards and a 10-dB cross-polarization isolation standard for small off-axis angles are also proposed. These changes should provide spacing for 37 U.S. satellites in each of the bands listed.

The project objectives are to design and develop a *capability for*:

- (1) Predicting and analyzing spectrum/orbital requirements of current and projected U.S. and international space-related programs,
- (2) Evaluating engineering and architectural designs,
- (3) Identifying and analyzing intentional/unintentional EMI,
- (4) Predicting saturation in spectrum usage/orbital positions,
- (5) Assessing means to accommodate growth, and
- (6) Supporting preparations for space services -WARC.

III. TECHNICAL REQUIREMENTS

To accomplish the project objectives, it will be necessary to design and develop a comprehensive Space Environment Data Base and Analysis Codes and Computer Programs.

SPACE ENVIRONMENT DATA BASE

The proposed Space Environment Data Base should consist of a file on electromagnetic and operational characteristics and a file on the deployment status of currently active and projected U.S. and international space systems, related earth segments, and network systems. The Electromagnetic and Operational Characteristics File should include three levels of information:

1. Level 1 - minimum data.
2. Level 2 - nominal and expanded data.
3. Documentation, reports, measured data.

The Deployment Status File should include four time-related information categories:

1. Current and active-deployed systems.
2. Approved-for-launch systems and scheduled dates.
3. Firm and funded development space system programs.
4. Future development plans and schedules.

A proposed data collection format has been designed by Rand and ECAC/IITRI and is intended for use in developing the Electromagnetic and Operational Characteristics File on Level 1.* The data will support preliminary interference analyses and will provide indications of the operational usage of systems. The format applies to communications, navigation, relay, sensor satellites, space transportation systems, their related earth segments, launch operations, and TT C operations. Technical characteristics of the hardware involved and operational characteristics of the system are to be reported. Other types of satellites, such as radar and solar power satellites, require additional data to describe the system adequately. Formats to accommodate these systems are being designed and will be published at a later date.

The data collection format (Appendix A) proposed by Rand and ECAC was designed to accommodate current and active deployed systems. The same format should be used to report known or projected data on systems in other categories of the Deployment Status File. Estimates or projections should be identified as such.

The proposed format is currently being tested and evaluated on Air Force space systems in cooperation with the Air Force Space Division Program Offices and the Communications Electronics Support Office (CSD/DC). It will be reviewed with NTIA, the FCC, Frequency Management Offices of the Department of Defense, and participants in the conference.

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* Appendix A: SPACE SYSTEMS DATA RECORD--Electromagnetic Characteristics and Operational Information for Space Systems and Related Earth Segments.

Design and modification of the Space Environment Data Base should be conducted as a continuing joint effort by The Rand Corporation, the DoD Electromagnetic Compatibility Analysis Center (ECAC), the DoD Frequency Management Agencies, NTIA, FCC, and other participating agencies. Responsibility for constructing and maintaining the Data Base and developing an analysis capability for space-systems planning has been assigned to the ECAC at Annapolis, Maryland.* ECAC already has the necessary computer and data-processing equipment, the trained personnel, and a substantial portion of the required space-environment data and associated analysis codes and programs. Additional facilities may be needed to process highly classified and proprietary data.

ECAC also maintains an extensive and active data base on the electromagnetic and operational characteristics of terrestrial and earth environment equipment that may affect some of the space-related programs.

Preliminary discussions have been initiated with NORAD, ADCOM (SPADOC), and other agencies about the acquisition and processing of needed data on the operational condition and status of space systems. Since these data will be at various levels of security and in some cases will include proprietary information, appropriate means for processing proprietary and classified information will need to be developed and approved by the cognizant agencies. A preliminary list of agencies and contacts was published in the Rand Report mentioned earlier and is being updated as the project develops.

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* Memorandum: "Electromagnetic Compatibility Analysis Center Support for Space Systems Planning," 25 June 1981, Office of the Under Secretary of Defense, Research and Engineering, Assistant Deputy Under Secretary (Technical Policy and Operations).

The Data Base should be made available--as needed, and under appropriate security procedures--to Rand space studies, to DoD, and to Government agencies and sponsored contractors conducting analyses in the subject areas.* The Data Base should be updated for satellite launches/decays and changes in space systems development plans to provide a continuing source of information for analyzing current and future space systems.

Prediction and analysis of probability of spacecraft collision and/or physical impact with space objects will not be addressed in this project. However, the Data Base should provide useful information on the ephemerides of current and future satellites, which is essential to such investigations.

ANALYSIS CODES AND COMPUTER PROGRAMS

The objectives are to devise analytic codes and computer programs for interrogating the Space Environment Data Base so that current and projected usage/saturation levels and impact of EM interference can be determined for the spectrum allocation, orbital positions of space systems, and related earth segments.

It may be necessary to develop new analysis techniques and usage/saturation criteria for each type of space communications, navigation relay, or sensor service. Since the results depend on space, time, frequency, message length, and scenario, usage and saturation

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* "Accessibility to the Data Base" will be discussed by J. Atkinson of ECAC in a separate briefing, and will be published in The Proceedings of the Conference.

levels will have to be determined for each elemental space volume of the system at various times and frequencies, at mean message lengths, and under different scenarios for different levels of usage. Space, even useful portions of space, is a very large volume. Conditions prevailing in one portion (or elemental volume) tend to be different from those prevailing in another.

For each authorized frequency band and/or channel, completely defined emissions, partially defined emissions (random in space or time), and undefined emissions (random in space and time) will have to be statistically combined and compared with receiver sensitivity, antenna gain, and system losses in order to derive a measure of band usage.

This correlation will provide a basis for projecting future demands on each allocated band in terms of the anticipated increase for users or frequency of use. After "saturation" is defined for each type of service, it should be possible to determine which usage rates are approaching saturation in an assigned frequency band and orbital position and how soon this is likely to occur.

Limits of orbital spacing are based on beamwidths of the earth station/terminal (may include mobile) antennas, electromagnetic interference criteria, and adherence to the ITU Radio Regulations. Hence, intentional and unintentional interference situations and their impact on usage/saturation levels should be assessed. Analysis of system vulnerability to intentional EM interference is an additional and essential requirement for hardened and secure systems.

Once suitable criteria have been determined and analyzed and programs have been developed, they will be applied to the Data Base to answer questions such as

1. What are the usage and saturation rates of existing and planned space communication systems?
2. Can a new system be added to the existing space environment and function as required? What will a new system (assuming it became operational) do to the existing systems?
3. What are intentional/unintentional interference situations, sources, and effects?
4. What will defined jamming situations do to a specified military data link that is already X percent saturated?
5. Which systems are the least conservative of spectrum?
6. Which systems approach orbital congestion?

Answers to questions such as these should make it possible to recommend communication practices, band allocations, and orbital assignments that will permit transmission of essential information within the available finite spectrum.

A list of proposed analysis codes and computer programs have been compiled to provide the capabilities for performing the types of analysis discussed and for meeting the overall project objectives (Table 1).

This list is based on a series of joint Rand/ECAC technical surveys and reviews of existing programs and those recommended for development. It will be augmented as the surveys and project activities continue and as user requirements are identified.

Table 1

Proposed Analysis Codes and Computer Programs

Title	Organization
1. Cull and coordination models:	
Space and earth segments	ECAC
ITU Radio Regulation Appendix 28, 29--Automation	ECAC, NTIA
Ground mobile satellite terminals	ECAC
2. Co-site analysis: space segment	ECAC
3. Co-site analysis: earth stations, fixed/mobile	ECAC
4. Intrasystem EMC Analysis: AF/IAP	RADC
5. Engineering and architectural design analysis:	
MITRE Interactive Communication Analysis Program (MICAP)	MITRE
Interference Analysis in Satellite Communications	MITRE
6. Intersystem EMC and vulnerability analysis:	
Geostationary orbit: Spectrum-Orbit Utilization Program (SOUP)	NTIA, NASA, ORI
Satellite Link Interference Prediction	Rand
Nongeostationary orbits and fixed/mobile stations	Rand
Environmental Analysis Model: frequency planning	ECAC
Deep Space RFI Prediction Program (DSIP-II)	JPL
MILSATCOM vulnerability analysis	AF/ESC, Bell
7. Saturation prediction and analysis:	Rand
System capacity	
Usage rate/efficiency	
Orbital positions	

IV. PROJECT STATUS AND FUTURE EFFORTS

During the formative period of the Rand project, and in subsequent Air Force/Rand reviews, we were advised to develop concepts and plans for listing the uses of the analysis programs and for accessing the data base, as required. It was assumed that ECAC would be assigned the responsibility of developing a data base and analysis capability with respect to military space systems for the purpose of improving EMC planning and minimizing the potential intersystem harmful EM interference. Other related space efforts, as listed in the Rand project objectives, may require the development and use of analysis capabilities by other DoD and government agencies and possibly by Air Force aerospace contractors.

Examples of such efforts would include capabilities for

1. EMC intrasystem analysis of space systems.
2. Assessments and analysis of Blue/Grey Forces interference or intentional Red Forces jamming.
3. Analysis of special space systems requiring compartmental data bases and 24-hour operational support.
4. Engineering analysis of architectural formulations of proposed space systems.
5. Determination of the transmission capacity of space systems, their usage rate and efficiency of use, and the predicted saturation of spectrum utilization and orbital positions.
6. Technical preparations space services WARC.

This extended support will require access to the ECAC data base and selected analysis computer programs. A joint conference on Space Systems Data Bases and Analysis Capabilities was organized to assist us and the ECAC in defining the items for inclusion in the data base and its subsequent updating, and in reviewing and evaluating existing and needed analysis programs. Representatives from industry and government agencies were asked to participate. The conference was conducted and hosted by ECAC, on November 17-19, 1981 at Annapolis, MD. ECAC will compile a report on the Proceedings.

Rand will be requesting the assistance of ECAC, the Aerospace Corporation, and other participating agencies in conducting assessments of the data base items and analysis programs required to meet the overall objectives outlined in this briefing. We hope to continue the design and development of analysis programs and to assist in determining the Air Force technical analysis and support requirements.

Among the objectives of the project is that it be timed to provide a usable capability for the technical development of Air Force positions on spectrum usage and orbital location issues for Space Services WARC. Attaining this objective will require the combined effort of and coordination with agencies outside Rand.

Study efforts aimed at assessing means to accommodate the growth of space systems and related proliferated earth terminals have not been discussed in this briefing. However, candidate techniques that may offer ways of accommodating increased proliferation of space data are being monitored and assessed as the project develops. Examples of such techniques include:

- Current and potential developments in data processing and compression, multibeam antennas, etc..
- Use of higher frequencies.
- Added spectrum allocations.
- More efficient energy dispersal.
- Improved side lobes of earth station antennas.
- Satellite data relay systems.

Appendix A

SPACE SYSTEMS DATA RECORD

Electromagnetic Characteristics and Operational Information for Space Systems and Related Earth Segments

Prepared by

The Rand Corporation
1700 Main Street
Santa Monica, CA 90406

and

IIT Research Institute for
DoD Electromagnetic Compatibility Analysis Center
North Severn
Annapolis, MD 21402

September 30, 1981

PRECEDING PAGE

INTRODUCTION

This data collection format is intended for use in developing the Electromagnetic and Operational Characteristics File on Level 1. The data will support preliminary interference analyses and will provide indications of operational usage of systems. The format applies to communications, navigation, relay, sensor satellites, space transportation systems, their related earth segments, launch operations, and TT&C operations. Technical characteristics of the hardware involved and operational characteristics of the system are to be reported. Other types of satellites, such as radar and solar power satellites, require additional data to adequately describe the system. Formats to accommodate these systems are being designed and will be published at a later date.

This data collection format was designed to accommodate current and active deployed systems. The same format will be used to report known or projected data on systems in the other Deployment Status File categories. Estimates or projections will be identified as such.

The number of forms to be completed will vary with the system being described. A space segment form will be completed for each satellite associated with the system and an earth segment form will be completed for each earth station associated with the system. Transmitter data and receiver data forms will be completed for each operating mode of each equipment nomenclature associated with the system.

If additional data items are required for systems being reported, please attach to the form as supplemental information with appropriate identifiers. Comments and suggestions on the data collection format are requested.

DATA SOURCES AND REFERENCES

Form Completed by:
Organization ____________________
Address ____________________
____

Point of Contact ____________________
Telephone Commercial: ____________________
Autovon: ____________________

Reference Documents (list by title, date, document number, and classification).

SUBMIT DATA TO:

Department of Defense
Electromagnetic Compatibility Analysis Center
North Severn, Annapolis, MD 21402
Attn: H. F. Mezzack XM

		Class/ Release/ Source
I. SYSTEM DATA		
A. General		
1. Mission Title/Common Name	______	______
2. Associated Satellite Names	______	______
3. Associated Terminal Names	______	______
4. Responsible Agency/Country	______	______
a. Research and Development of System	______	______
b. Acquisition	______	______
c. Control	______	______
d. User	______	______
5. Control Center Names and Locations	______	______
6. System Function/Type (ex: data, DBS, comm, passive reflector, etc.)	______	______
7. Average Usage Factor		
Current	______	______
Projected	______	______
8. Link Data		
a. Uplink Margin	______	______
b. Uplink Maximum Possible Signalling Rate or Bandwidth	______	______
c. Uplink Maximum Data Rate or Capacity	______	______
d. Downlink Margin	______	______
e. Downlink Maximum Possible Signalling Rate or Bandwidth	______	______
f. Downlink Maximum Possible Signalling Rate or Bandwidth	______	______
g. Lowest Equivalent Satellite Link Noise Temperature	______	______
9. GMF S Note	______	______
10. Operating Modes	______	______
	______	______
	______	______
	______	______
	______	______
	______	______
	______	______

		Class/ Release/ Source
II. EARTH STATION		
A. Administrative		
1. Licensee/Organization/Unit	______	______
2. City or Base (Station Name)	______	______
3. Manufacturer	______	______
4. Station Class	______	______

II. EARTH STATION PARAMETERS		Class/ Release/ Source
B. Physical		
1. Site Name, Country	____________	________
2. Location		
a. Latitide	____________	________
Longitude	____________	________
b. UTM Grid Reference		
Northing	____________	________
Easting	____________	________
Grid Zone	____________	________
Spheriod	____________	________
3. Antenna Azimuth (if geosynchronous satellite)	____________	________
4. Fixed/Mobile	____________	________
5. Platform Type	____________	________
6. Radius of Movement*	____________	________
7. a. Rain-Climatic Zone	____________	________
b. Radio-Climatic Zone (A, B, C)*	____________	________
c. Horizon Elevation Profile*	____________	________
8. Refractivity	____________	________

*Attach Information

Class/
Release/
Source

II. EARTH STATION TRANSMITTERS

C. Technical

0. Equipment Nomenclature/Operating Mode

1. Bandwidth ________ ________
2. Frequency Range ________ ________
3. Modulation ________ ________
4. Power ________ ________
5. Power Type ________ ________
6. Harmonic Attenuation ________ ________
7. Spurious Attenuation ________ ________
8. RF Filter, Filter Type ________ ________
   3 dB Bandwidth/Number of Poles/Q ________ ________
   or Off-Frequency/Relative Level ________ ________
   ________ ________
   ________ ________
   ________ ________
9. Noise Floor ________ ________
10. Data Rate/Number of Voice or Video Circuits ________ ________
11. Emissions Description: ________ ________
   (if different from RF filter spectrum)
   3 dB Bandwidth/Roll-Off ________ ________
   Frequency/Relative Attenuation
12. Access Mode ________ ________
13. Link Type ________ ________
14. Output Device ________ ________

Electrooptic (e-o) Transmitter
1. Nomenclature ________ ________
2. Wavelength ________ ________
3. Output Device ________ ________
4. Power Output ________ ________
5. Emissions Spectrum
   Off-Frequency/Relative Level ________ ________
   ________ ________
   ________ ________
   3 dB Bandwidth/Roll-Off ________ ________
6. Data Rate ________ ________

Class/
Release/
Source

II. EARTH STATION RECEIVER

D. Technical

0. Equipment Nomenclature/Operating Mode

1. RF Bandwidth ________________ ________
2. Frequency Range ________________ ________
3. Modulation ________________ ________
4. RF Filter Type ________________ ________
   3 dB Bandwidth/Number of Poles (Roll-off)/Q ________________ ________

   or Off Frequency/Relative Level ________________ ________
   ________________ ________
   ________________ ________
   ________________ ________

5. Number of IF Stages ________________ ________
6. For Each IF Stage:
   IF Frequency ________________ ________
   3 dB Bandwidth/# Poles (Roll-off)/Q ________________ ________
   or Frequency/Relative Level ________________ ________
   ________________ ________
   ________________ ________

   LO Frequency ________________ ________
7. Spurious Rejection ________________ ________
8. Harmonic Rejection ________________ ________
9. Image Rejection ________________ ________
10. Required Signal-to-Noise Ratio ________________ ________

11. Noise Figure ________________ ________
12. Noise Equivalent Power/Responsivity ________________ ________

13. Sensitivity/Sensitivity Criterion ________________ ________

14. Baseband Bandwidth ________________ ________
15. Access Mode ________________ ________
16. G/T ________________ ________
17. Effective Receiver Noise Temperature ________________ ________

e-o Receiver
1. Nomenclature ________________ ________
2. Wavelength ________________ ________
3. Detector Type ________________ ________
4. Sensitivity and Basis ________________ ________
5. RF Susceptibility ________________ ________
6. Coherent/Incoherent ________________ ________
7. Detector Noise Voltage ________________ ________

		Class/ Release/ Source
III. SPACE SEGMENT		
A. Administrative		
1. Mission Title/Common Name	______________	________
2. International Designator	______________	________
3. NORAD-Space Object Number	______________	________
4. Inter-Range Operations Number	______________	________
5. Satellite Launch/Expiration Date	______________	________
6. Bringing Into Use Date	______________	________
7. Manufacturer	______________	________

Class/
Release/
Source

III. SATELLITE ORBITAL PARAMETERS

B. Physical

1. Orbit Type ______________ ______

Elliptical Orbits

2. Orbit Inclination ______________ ______
3. Right Ascenscion of Ascending Node ______________ ______
4. Orbital Eccentricity ______________ ______
5. Argument of Perigee ______________ ______
6. Mean Motion Rate ______________ ______
7. Epoch ______________ ______
8. Inclination ______________ ______
9. Semi-latus Rectum ______________ ______
10. Time of Perigee Passage ______________ ______
11. Apogee ______________ ______
12. Perigee ______________ ______
13. Nodal Period ______________ ______
14. Mean Anomoly ______________ ______
15. Eccentric Anomoly ______________ ______
16. Active Portion of Orbit ______________ ______
17. First Time Derivative of Mean Motion Rate ($n_o/2$) ______________ ______
18. Second Time Derivative of Mean Motion Rate ($n_o/6$) ______________ ______
19. Drag Coefficient (B*) ______________ ______
20. Element Set Number ______________ ______

Geosynchronous Orbits

2. Longitude of Station in Orbit ______________ ______
3. Station Keeping Limits ______________ ______
4. Inclination ______________ ______

Class/
Release/
Source

III. SPACE STATION TRANSMITTER

C. Technical

0. Equipment Nomenclature/Operating Mode

1. Bandwidth
2. Frequency Range
3. Modulation
4. Power
5. Power Type
6. Harmonic Attenuation
7. Spurious Attenuation
8. RF Filter
   3 dB Bandwidth/Number of Poles/Q

   Off-Frequency/Relative Attenuation

9. Modulation Type
10. Data Rate/Number of Voice or Video Circuits

11. Emissions Descriptions
    3 dB Bandwidths/Roll-Off
    Frequency/Relative Attenuation

12. Noise Floor
13. Access Mode
14. Downlink Mode
15. Output Device

e-o Transmitter
1. Nomenclature
2. Wavelength
3. Output Device
4. Power Output
5. Emissions Spectrum
   3 dB Bandwidth/Roll-off
   Off-Frequency/Relative Level

6. Data Rate

Class/
Release/
Source

III. SPACE STATION RECEIVER

D. Technical

0. Equipment Nomenclature/Operating Mode

1. RF Bandwidth
2. Frequency Range
3. Modulation
4. RF Filter Type
   3 dB Bandwidth/Number of Poles (Roll-off)

   or Off-Frequency/Relative Level

5. Number of IF Stages
6. For Each IF Stage:
   IF Frequency
   3 dB Bandwidth/# Poles (Roll-off)
   or Frequency/Relative Level
   LO Frequency

7. Spurious Rejection
8. Harmonic Rejection
9. Image Rejection
10. Required Signal=to=noise Ratio

11. Noise Figure
12. Noise Equivalent Power/Responsivity

13. Sensitivity/Sensitivity Criterion

14. Baseband Bandwidth
15. Access Mode
16. Effective Receiver Noise Temperature
17. G/T

e-o Receiver
1. Nomenclature
2. Wavelength
3. Detector Type
4. Sensitivity and Basis
5. RF Susceptibility

6. Coherent/Incoherent
7. Detector Noise Voltage

		Class/ Release/ Source
IV. EARTH STATION ANTENNA		
A. Administrative		
1. Equipment Nomenclature	____________	________
2. Operating Agency	____________	________
3. Transmit Mode	____________	________
4. Receive Mode	____________	________
5. Manufacturer	____________	________

IV. EARTH STATION ANTENNA		Class/ Release/ Source
B. Physical		
1. Antenna Type	____________	________
2. Antenna Dimensions	____________	________
3. Horizontal Arc Scanned	____________	________
4. Vertical Arc Scanned	____________	________
5. Feedpoint Height	____________	________
6. Azimuth Pointing Angle	____________	________
7. Elevation Pointing Angle	____________	________

		Class/ Release/ Source
IV. EARTH STATION ANTENNA		
C. Technical		
1. Gain	____________	________
2. Gain Pattern (Use figure if available)	____________	________
Angle Off Boresight/Relative Level	____________	________
3. Polarization/Polarization Discrimination	____________	________
4. Type of Illumination	____________	________
5. Efficiency	____________	________
6. Antenna Noise Temperature	____________	________
7. Horizontal Beamwidth	____________	________
	____________	________
8. Vertical Beamwidth	____________	________
	____________	________
9. Optics:		
Tranmittance	____________	________
Aperture Diameter	____________	________
Field of View	____________	________
Beam Divergence	____________	________

		Class/ Release/ Source
V. SPACE STATION ANTENNA		
A. Administrative		
1. Equipment Nomenclature	______	______
2. Operating Agency	______	______
3. Transmit Mode	______	______
4. Receive Mode	______	______
5. Manufacturer	______	______

		Class/ Release/ Source
V. SPACE STATION ANTENNA		
B. Physical		
1. Antenna Type	______________	________
2. Antenna Dimensions	______________	________
3. Beam Type (spot, global, etc.)	______________	________
4. Position in X,Y,Z Coordinates	______________	________
5. Antenna Feed	______________	________

Class/
Release/
Source

V. SPACE STATION ANTEN'A

C. Technical

1. Gain
2. Gain Pattern (Use figure if available)

   Angle Off Boresight/Relative Level

3. Polarization/Polarization Discrimination

4. Type of Illumination
5. Efficiency
6. Antenna Noise Temperature
7. Horizontal Beamwidth

8. Vertical Beamwidth

9. Optics:
   Tranmittance
   Aperture Diameter
   Field of View
   Beam Divergence

Class/
Release/
Source

VI. MODULATION DESCRIPTION

A. Analog

1. Modulation Type ______________ ______
2. Baseband Signal Description

   ______________ ______
3. FM
   - a. Peak Deviation ______________ ______
   - b. Freq. Limits of Modulating Signal

     ______________ ______
   - c. Pre-emphasis/De-emphasis

     ______________ ______
4. FDM/FM
   - a. Number of Voice Channels

     ______________ ______
   - b. Frequency Limits of FDM Baseband

     ______________ ______
   - c. Peak Carrier Deviation ______________ ______
   - d. Pre-emphasis/De-emphasis

     ______________ ______
   - e. RMS Deviation ______________ ______
5. TV
   - a. Baseband Modulation (TV System) (e.g., PAL, SECAM, NTSC)

     ______________ ______
6. AM
   - a. Modulation Index ______________ ______

		Class/ Release/ Source
VI. MODULATION DESCRIPTION		
B. Digital		
1. Modulation Type	____________	________
2. Baseband Signal Description	____________	________
	____________	________
	____________	________
	____________	________
3. Information Rate	____________	________
4. Signalling Rate	____________	________
5. Applied Coding	____________	________

Class/
Release/
Source

VI. MODULATION DESCRIPTION

C. Spread Spectrum

1. Type ______ ______
   a. Direct Sequence ______ ______
      1. Code Length ______ ______
      2. Code Type ______ ______

   b. Frequency Hopping ______ ______
      1. Number of Channels ______ ______
      2. Channel Bandwidth ______ ______
      3. Channel Spacing ______ ______
      4. Hop Rate ______ ______
      5. Hopping Bandwidth ______ ______

   c. Chirp (Pulsed FM)
      1. Frequency Sweep ______ ______
      2. Sweep Time ______ ______

   d. Time Hopping ______ ______
      1. Gate Length ______ ______
      2. Period ______ ______

   e. Hybrid Systems (Describe)

______ ______
______ ______
______ ______
______ ______
______ ______

2. Baseband Data Rate ______ ______
3. PN Code Rate (Chip Rate) ______ ______
4. Processing Gain ______ ______
5. Synchronization Type

______ ______

6. Signalling Rate ______ ______

Class/
Release/
Source

VI. MODULATION DESCRIPTION

D. Pulsed Systems

1. Pulse Width ______________________ ____________

2. Pulse Rise Time ______________________ ____________

3. Pulse Fall Time ______________________ ____________

4. Pulse Repetition Rate ______________________ ____________

5. Frequency Deviation on Rise ______________________ ____________

6. Frequency Deviation on Fall ______________________ ____________

7. Chirped Frequency Shift ______________________ ____________

		Class/ Release/ Source
VII. ACCESS MODES		
A. TDMA		
1. Frame Rate	______	______
2. Preamble Length	______	______
3. Preamble Rate	______	______
4. Slot Length	______	______
5. Number of Slots	______	______
6. Guardband	______	______
B. FDMA*		
1. Number of Channels	______	______
2. Channel Bandwidth	______	______
3. Channel Spacing	______	______
C. CDMA or SSMA		
1. Code Length	______	______
2. Number of Users (nets)	______	______
3. Code Rate	______	______
4. Code Type	______	______
D. OTHER TYPE		
	______	______
	______	______
	______	______
	______	______
	______	______

* If channel bandwidths and spacing are not uniform, attach description

GLOSSARY
TRANSMITTER PARAMETERS

Access Mode - method by which a communications satellite accommodates multiple network users, i.e., TDMA, FDMA, etc.

Average Power - the power delivered to the transmitter output averaged over a modulation cycle.

Bandwidth - difference between the frequencies at which attenuation is less than a specified amount.

Baseband - the band of frequencies occupied by the signal before it modulates the carrier frequency to form the transmitted radio signal.

Chirp Frequency Shift - difference between the maximum and minimum frequencies of a chirped pulse.

Data Rate - baseband digital information rate (bits per second).

Downlink Mode - spot beams, b'cast, etc.

Emissions Description - a set of relative power levels at frequencies offset from the carrier frequency.

Filter Type - generic circuit type used in filter construction (for example: Butterworth, Elliptical, etc.).

Frequency Limits of Modulating Signal - baseband bandwidth of input signal.

Harmonic Attenuation - relative level of emissions (amount of suppression of output signal) at multiples of the desired output frequency.

Margin - excess of received signal levels beyond that needed for proper operation.

Modulation - method of modifying some characteristics(s) (phase, frequency, or amplitude) of a wave to correspond to some other wave or data.

Noise Floor - minimum noise output of a system.

Operating Mode - designation to identify a method in which the system can be used.

Output Device - final stage power amplification device (for example: travelling wave tube).

Peak Power - (for pulsed systems) mean output power during pulse duration.

Pole - value for which the network function of a circuit is infinite.

Pre-Emphasis - a process that emphasizes the magnitude of some frequency components in order to reduce adverse affects such as noise.

Pulse Repetition Frequency - rate (in Hz or pps) at which pulses are transmitted.

Pulsewidth - time interval between points on the leading and trailing edge of a pulse which are $1/2$ the peak pulse amplitude.

Q - quality factor, ratio of resonant frequency to 3 dB bandwidth.

RF Filter - final filter at the output of the transmitter.

Rise Time (fall time) - time interval required for the pulse to rise (fall) from 10% to 90% (90% to 10%) of its peak amplitude.

Roll-Off (fall-off) - rate of increasing attenuation of an emissions spectrum with frequency.

Signalling Rate - actual rate of transmitting modulated pulses. (Symbols per second.)

Spurious Attenuation - amount of suppression of output signal (relative level of emissions) outside the bandwidth sufficient to ensure the desired transmission (excluding harmonics).

Stretched Compression Pulse Width Indicator - (RADAR) coding and processing of a single pulse of long duration to one of short duration and high range resolution.

Symbol - a transmitted, modulated, pulse.

System Data Rate - total throughput of satellite system given in either bps, equivalent video circuits, or equivalent voice channels.

Usage Factor - communications systems: ratio of utilized information transmission capability to that available. Other systems: fraction of utilized operational time.

RECEIVER PARAMETERS

Access Mode - method by which a communications satellite accommodates multiple network users, i.e., TDMA, FDMA, etc.

Baseband Bandwidth - frequency difference between the 3 dB points of the information bearing signal.

Equivalent Satellite Link Noise Temperature - noise temperature at the input of the earth station receiver. Corresponds to the RF noise power which produces the total observed noise at the output of the satellite link.

G/T - radio station figure-of-merit. Ratio of antenna gain-to-equivalent noise temperature of receiver system.

IF Stage - frequency translation and filtering circuit.

Image Rejection - rejection at a frequency separated from the tuned frequency by twice the IF frequency. The image frequency may be above or below the tuned frequency depending on whether the local oscillator frequency is above or below the tuned frequency.

Modulation - method of wave modification that an equipment is designed to receive.

Noise Equivalent Power - the value of radiation which produces, in the detector, an RMS S/N ratio of one.

Noise Figure - measure of the noise added to an input signal by a receiver.

Off-Frequency - a given frequency separation from the tuned frequency.

Pole - value for which the network function of a circuit is infinite.

Processing - on-board signal manipulation.

Processing Mode - description of on-board signal handling (for example: regenerative repeater).

Required Signal-to-Noise (S/N) Ratio - S/N needed for proper signal processing at a specific point.

Relative Level - rejection compared to minimum (in-band) case.

RF Bandwidth - difference between the frequencies at which RF filter rejection is less that 3 dB.

Roll-Off (fall-off) - rate of increasing signal rejection of receiver selectivity, with respect to frequency.

Sensitivity - minimum input signal level required to produce an output having a given S/N. Lower limit of useful input signal power.

Sensitivity Criteria - method or threshold used to determine receiver sensitivity.

Spurious Rejection - relative rejection level for signals outside the bandwidth sufficient to ensure the desired reception.

System Bandwidth - total bandwidth of all on-board receivers.

Transmittance - ratio of flux emerging to flux incident.

ORBITAL PARAMETERS

Active Portion of Orbit - for non-geosynchronous satelliites, the amount of time during each orbit when RF links(s) are active.

Anomaly - angle from the focus of the orbital ellipse between the line of the apsides of the orbit and the point of closest approach to the focus, in the direction of travel. Also, true anomaly.

Apogee - orbital point most distant from center of earth.

Argument of the Perigee - angle from the ascending node to the perigee along the path of the orbit in the direction of spacecraft motion.

Ascending Node - point (longitude) where the satellite crosses the equatorial plane from the southern to the northern hemisphere.

Epoch - time at which specified orbital parameters are valid.

Geostationary Orbit - nominally circular satellite orbit having a period of one day and an orbital inclination of zero.

Geosynchronous Orbit - satellite orbit where the period is one day.

Longitude (for Geosynchronous satellites) - longitude in degrees referenced to the prime meridian of the point on the equator directly beneath the satellite (also "orbital slot").

Longitude of Ascending Node - see ascending node.

Mean Anomaly - angle that would be described by the radius vector had it moved uniformly at the average angular motion.

Mean Motion Rate - average angular velocity of satellite (360° divided by the satellite period).

Nodal Period - time to complete one orbit.

Non-Geosynchronous or Non-Geostationary Orbit - orbit where the period does not equal one day.

Orbital Eccentricity - for elliptical orbits, a measure of the "flatness" of the ellipse. The ratio of the distance from the center of the ellipse to the focus and the length of the semi-major axis.

Orbital Inclination - angle between the orbital plane and the earth's equatorial plane. Measured at point where satellite passes from southern to northern hemisphere.

Perigee - orbital point closest to center of earth.

Right Ascension of Ascending Node - angular distance along the celestial equator from the vernal equinox eastward to the point where the satellite passes from the southern to northern hemisphere.

Semi-Latus Rectum - distance, on a line perpendicular to the major axis, from the focus to the orbital ellipse.

Station Keeping Limits (for Geosynchronous Satellites) - tolerance of the satellites's position in the North/South and East/West directions.

Time of Perigee Passage - epoch when satellite passes through the perigee.

MODULATION PARAMETERS

Channel Spacing - separation between center frequencies of FH channels.

Chirp (Pulsed FM) Spread Spectrum - sweeping of an FM carrier over a wide frequency band during a pulse interval.

Code Length - block length of PN code.

De-Emphasis - process of restoring pre-emphasized signals.

Direct Sequence Spread Spectrum - modulation of a carrier by a digital code sequence whose chirp rate is much higher than the information bandwidth.

Frequency Division Multiplexing/Frequency Modulation (FDM/FM) - FM transmission of a group of voice channels multiplexed together.

Frequency Hopping Spread Spectrum - shifting of the carrier frequency to preset channels in a pattern set by a code sequence.

Frequency Modulation (FM) - modulation of a sine-wave carrier so that its instantaneous frequency differs from the carrier frequency by an amount proportional to the instantaneous amplitude of the modulating signal.

Frequency Sweep - difference in frequency limits through which a chirped pulse is swept.

Gate Length - period during which system is turned on.

Hop Rate - rate at which FH system jumps from one channel to another.

Modulation - method of modifying some characteristic(s) (phase, frequency, or amplitude) of a wave to correspond to some other wave or data.

Peak Deviation - maximum frequency difference in FM systems between the instantaneous frequency and the carrier frequency.

Period - time betwen successive gates or pulses.

Pre-Emphasis - a process that emphasizes the magnitude of some frequency components to reduce adverse effects such as noise.

Pseudonoise (PN) Code - a binary sequence with a desirable trans-orthogonal auto-correlation property.

Processing Gain - improvement in S/N obtained by decoding spread spectrum mode transmissions.

Spread Spectrum - transmission of an information-bearing signal over a bandwidth wider than necessary.

ANTENNA PARAMETERS

Antenna Noise Temperature - the average temperature of all noise sources in the antenna pattern.

Beamwidth - angle between which the antenna gain is within a given amount relative to the maximum gain.

Divergence - rate of beam spreading.

Efficiency - ratio of total power output by the antenna to the power received.

Gain - ratio of output power radiated (or received) in a given direction to that which would be radiated (or received) by an isotrobic antenna.

Polarization - description of the electric vector transmitted from an antenna (or which an antenna is designed to receive).

ACCESS MODE PARAMETERS

Code Division Multiple Access (CDMA) - communication through use of difference codes at a common carrier frequency.

Frame Rate - in TDMA systems, time between bursts of a given user.

Frequency Division Multiple Access (FDMA) - communication through use of difference frequency bands within a common repeater.

Guardband - in TDMA, time between slots; in FDMA, unused frequency between channels.

Preamble - in TDMA systms, synchronization, acquisition, and bit timing information.

Slot Length - in TDMA systems, burst times for individual system users.

Time Division Multiple Access (TDMA) - communication through non-overlapping time-sequenced bursts of transmissions through a common repeater.

Symbol Rate - channel output signaling rate.

Synchronization Type - method of acquiring and maintaining synchronization.

Sweep Time - pulse time in a chirped system.

Time Hopping Spread Spectrum - pulsing of output signal controlled by a PN code.

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